Sampling TMDL Implementation Rates and Patterns in the North Central US

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) Total Maximum Daily Load (TMDL) program has accounted for the listing of over 40,000 impaired waters nationwide and the development of over 37,000 TMDLs since the program's creation. Case-specific accounts of implementation are widespread, but the actual rate of implementing TMDLs nationally or regionally has remained virtually unknown because full census and tracking of every implemented practice would be an overwhelming if not impossible task. To gain insights on implementation, EPA's TMDL Program Results Analysis Project conducted a sample-based analysis of TMDL implementation rates and characteristics in the six EPA Region 5 states (IL, IN, MI, MN, OH and WI). A probabilistic sample was drawn from all TMDLs established through FY2007. Sampled TMDLs were allocated proportionally to states based on each state's total TMDL production. Regional but not specific state-level statistics were the goal of the study. Subpopulations of interest contrasted older (through FY2003) versus newer (FY2004 – FY2007) TMDLs, and nonpoint-source (NPS)-only TMDLs versus point source (PS)-only and mixed (PS/NPS) TMDLs. The project team extracted information on each of the 138 sample TMDLs and their proposed NPS and PS controls from EPA data systems in advance of working with each state to verify implementation rates and patterns across the Region. Findings demonstrated that, within a +/- 10% margin of error at 90% C.I., an estimated 80.3% of Region 5 TMDLs were at least partially implemented. Full implementation was uncommon. No implementation was observed in approximately 20% of the sample, but the diffuse nature of control practices typical of many TMDLs made complete verification of every practice difficult. Among subpopulations, implementation rates did not differ significantly between older or newer TMDLs, but the mixed TMDLs implementation rate exceeded the NPS-only rate by 16.1%. Implementation plans existed for 79.6% of TMDLs, and NPS-only TMDLs showed more plans than the mixed TMDL subpopulation. TMDLs generated as part of large watershed, multi-TMDL efforts comprised 13.2% more of the newer TMDLs subpopulation than the older TMDLs subpopulation. Post-analysis steps included exploring GIS data on the watershed traits of each sampled TMDL for other possible associations with patterns of implementation. Analysis of predominant land cover in the samples' watersheds did not reveal significant differences among implementation rates associated with urbanized, heavily agricultural, lightly agricultural, and rural non-agricultural watersheds.

KEYWORDS

Implementation, TMDL, Assessment, BMPs, Permits, Results Analysis

INTRODUCTION

Tens of thousands of Total Maximum Daily Loads (TMDLs) have been completed in the history of the TMDL program. The temporal and geographic distribution of this universe of TMDLs is well documented (e.g., numbers of TMDLs completed each year, numbers of TMDLs from each state) and retrievable through the US Environmental Protection Agency (EPA) ATTAINS data system (EPA 2009a, EPA 2009b). EPA compiles and tracks impaired waters and completed TMDLs through information submitted by states, authorized tribes and territories (collectively referred to as states in this paper). The nature of impairments addressed in these TMDLs is well documented at general levels (e.g., PS, NPS, mixed sources; by listing cause/impairment type; by waterbody name, watershed, and state). TMDL implementation, however, is not well documented. Implementation rates and patterns are not well understood, despite the fact that insights on implementation would be critically valuable to guide program management decisions and directions. The lack of TMDL implementation data is attributable to many factors: EPA does not have authority to require state TMDL implementation or implementation tracking and reporting; few states track implementation actions; tracking implementation would further burden limited state programs; implementation often involves many diffuse and decentralized individual actions not under EPA control, with no obligation to report actions to EPA; EPA has not had an Information Collection Request (ICR) authorizing collection of data nationally on implementation actions; and a centralized data structure or process for tracking implementation data has not been developed.

Recently, a program evaluation by the EPA Office of Inspector General (OIG 2007) recommended that the TMDL program report on implementation progress nationwide and annually. This recommendation matched EPA and state TMDL programs' interest in knowing more about TMDL implementation rates, but did not acknowledge the extreme difficulty and expense of tracking all implementation actions related to all TMDLs. A census approach to documenting individual implementation actions was not feasible within the normal scope of the EPA TMDL program budget, due to the factors provided above. The TMDL program determined that it might be possible to gain enough data from a sample to develop valid estimates of implementation rates and primary associated characteristics. With the cooperation of the EPA Office of Water, EPA Office of Research and Development, EPA Region 5 (North-Central US) and the States of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin, we designed and carried out a probabilistic sample approach capable of addressing selected attributes of TMDL implementation at a regional scale.

METHODOLOGY

In 2008 and early 2009, EPA designed and conducted a TMDL implementation sampling pilot study in Region 5 (Tetra Tech, Inc. 2009). The purpose of the study was to conduct an analysis of TMDL implementation rates and other characteristics related to implementation in the six EPA Region 5 states. The basic characteristics of interest included:

- Installing Best Management Practices (BMPs) that contribute to addressing the Load Allocation of a given TMDL, through Section 319 (or, to the extent available, other) projects;

- Incorporating the Waste Load Allocations (WLAs) of a given TMDL in National Pollutant Discharge Elimination System (NPDES) (or other) permits;
- Completion of an Implementation Plan; and
- Associations among observed implementation rates and implementation plan existence, age or type of TMDL, watershed/multi-TMDLs vs single-segment TMDLs, and watershed land use traits.

To characterize implementation, we defined three categories of TMDL status: full implementation, partial implementation and no implementation. Full implementation could only be designated as such if all the practices (i.e., BMPs, permits) planned for implementing a TMDL were verified as completely installed. Sample TMDLs were categorized as having no implementation if no evidence of installed practices could be found. Partial implementation was used to describe all samples that displayed a mix of some installed/some not installed practices, or some installed/some unverified practices. Despite these limits to what could be categorized and quantified statistically, we gathered substantially greater details about each TMDL (Table 1).

The project analyzed a sample of approved TMDLs within Region 5 to estimate implementation status at the Regional level within a +/- 10 percent margin of error at 90 percent confidence. The list of TMDLs was extracted from an ATTAINS data system query and contained a Region 5 statistical universe of 2,228 TMDLs approved through FY2007. Although new TMDLs are completed continually, we chose to limit the sample to TMDLs completed through the end of FY2007 to leave at least one year beyond TMDL approval to allow implementation actions to begin. Subpopulations of interest included older and newer TMDLs (through FY2003, and FY2004 to FY2007), and nonpoint-only and point source related (point-only and mixed) TMDLs. Sufficient numbers of point source-only TMDLs were not available to constitute a separate subpopulation. The study was not designed to obtain state-level statistically valid results. Based on the subpopulations, desired accuracy, and desired statement parameters, the estimated minimum sample size was 126. Additional TMDLs (15) were added to compensate for expected non-response or other data issues, yielding a sample selection of 141 TMDLs. Three unsuitable sample TMDLs were subsequently deleted from the study and the final study sample therefore included 138 TMDLs (Figure 1). The samples were proportionally allocated among Region 5 states based on their relative amount of TMDLs produced; the single-state totals ranged from 10 to 42 TMDL samples.

Figure 1: Locations of Region 5 sample TMDLs

Sources of information used in collecting the necessary data included the TMDL reports and decision documents; TMDL implementation plans; online web pages and databases; permit and grant documentation; and state TMDL, permitting and nonpoint source personnel. The data collection protocols identified the sources of information relevant to each data element and the priority order for their review. For example, the available TMDL-related reports were

Table 1 - Information collected on each TMDL in the study sample.	
Basic TMDL Reference Information	
TMDL State	Pollutant Description
TMDL Sample #	TMDL Type
Waterbody Name	TMDL Fiscal Year
TMDL ID	
Preliminary TMDL-Level Information	
General Categories of PS	Status of BMP Implementation
Total WLA	Status of BMP Planning
WLA Units	WLA Allocation Details
NPDES Facility Names	Other Project Names
NPDES Facility IDs	Sponsoring Sources
NPDES Facility Type	Funding
Individual WLAs for each NPDES ID	Status of Project Implementation
Individual WLA Units	WLA Allocation Details
Status of incorporating WLAs into NPDES Permits	Status of Project Planning
Issuance/Reissuance Date	Included in TMDL Report or Post-TMDL
General Categories of NPS	LA Allocation Details
Total LA	LA Units
319 Project Names	319 Project IDs
Year of Funding	TMDL Implementation Status
Funding	Source of Funding Information
Status of BMP Implementation	Status of BMP Planning
Source of BMP Implementation	BMP Planning Source
TMDL Implementation Plan Status	Is Segment-Pollutant Combination Part of Multi-TMDL/Watershed TMDL Analysis?
What Date Did TMDL Implementation Begin?	Total # of TMDLs Finalized in TMDL Document
Within-TMDL Information (Additional Data Not Included In TMDL Document)	
NPDES Facility Names	Status of BMP Planning
NPDES Facility IDs	Project Name
NPDES Facility Type	Sponsoring Sources or Permit Number
Issuance/Reissuance Date	Funding
Status of WLA Implementation	Status of Project/Permit Implementation
319 Project Name	Status of BMP Planning
319 Project IDs	Evidence of Water Quality Improvements, and Source
Funding	Data Mining Contact(s)
Funding Source	Status of BMP Implementation
Project Implementation Source	Data Mining/Compilation Issues
Status of Project Planning	Project Planning Source
Other Project Names	Sponsoring Sources
TMDL Implementation Summary Details	
Overall TMDL Implementation Status	TMDL Implementation Plan Completed?
PS-Related Implementation Status	TMDL Developed as Part of Multi-TMDL or Watershed TMDL?
NPS-Related Implementation Status	TMDL Implementation Within the Watershed but not on TMDL Segment
Overall TMDL Implementation Status Up Through FY 2003	Parallel but Unrelated Implementation
Overall TMDL Implementation Status from FY 2004 Through FY 2007	Evidence of Water Quality Improvements?
Evidence Sources	Data Mining Issues
Contacts and Sources	
Contact Name	Contact Phone
Contact E mail	Source
Source Address	Reason Used

reviewed first for any relevant information prior to searching other information sources such as online databases. State personnel were not contacted until the readily available reports and other sources of information were analyzed for remaining data gaps. This was done to eliminate any unnecessary burden. For each TMDL, five categories of data were recorded. The numerous data elements were not intended to each generate statistics within the desired error and confidence bounds in our design, but rather were gathered to provide greater background details about the sample TMDLs to complement the primary, statistically quantified statements (see the Results section below) that were the focus of the study. The project used a standardized Excel spreadsheet and Access database to compile and organize the information. The spreadsheet was used to document the available data as they were collected. The data were then inserted into the database to standardize data storage and facilitate data querying.

RESULTS

The study design focused on quantifying the following seven statements concerning the full sample or specific subpopulations of the sample. Results below are presented both as actual frequencies in the sample and population percent estimates after sample weighting. Quantities in parentheses indicate the number of sample TMDLs for which the statement was true (numerator) and the total number of sample TMDLs in the population or subpopulation that the statement addresses (denominator). Estimated percentages were derived after taking into account appropriate sample weighting factors for each subpopulation:

1. The estimated overall rate of partial to full TMDL implementation for all types and dates of TMDLs in Region 5 is 80.3 percent (104/138).

2. The estimated rate of partial to full TMDL implementation for mixed and point source TMDLs in Region 5 is 88.8 percent (46/50).

3. The estimated rate of partial to full TMDL implementation for TMDLs including only nonpoint sources is 72.7 percent (58/88).

4. The estimated rate of partial to full implementation for TMDLs in Region 5 approved in FY2003 or earlier is 76.6 percent (39/51).

5. The estimated rate of partial to full implementation for TMDLs in Region 5 approved between FY2004 and FY2007 is 81.0 percent (65/87).

6. The estimated proportion of TMDLs in Region 5 with an implementation plan is 79.6 percent (117/138).

7. The estimated proportion of TMDLs in Region 5 that were developed through multi-TMDL or watershed-TMDL analysis is 95.7 percent (123/138).

Although full implementation of every practice related to a given TMDL was uncommon (less than 3% of total), over ¾ of the sample TMDLs had been at least partially implemented. As statements 1 through 5 all address implementation rates, they allow for some comparison among subpopulations (Figure 2). One apparent pattern is that older and newer TMDL subpopulations did not differ significantly in implementation rates (76.6% and 81.0% respectively). In contrast, a 16.1% difference was observed in the rates of implementing NPS-only TMDLs (72.7%) and mixed NPS-PS TMDLs (88.8%).

Figure 2. Comparison among sample population and subpopulations of estimated percent of partially to fully implemented sample TMDLs. Note rates vary around approximately ¾ partial to full implementation, and the difference of 16.1% between NPS-only and mixed TMDLs.

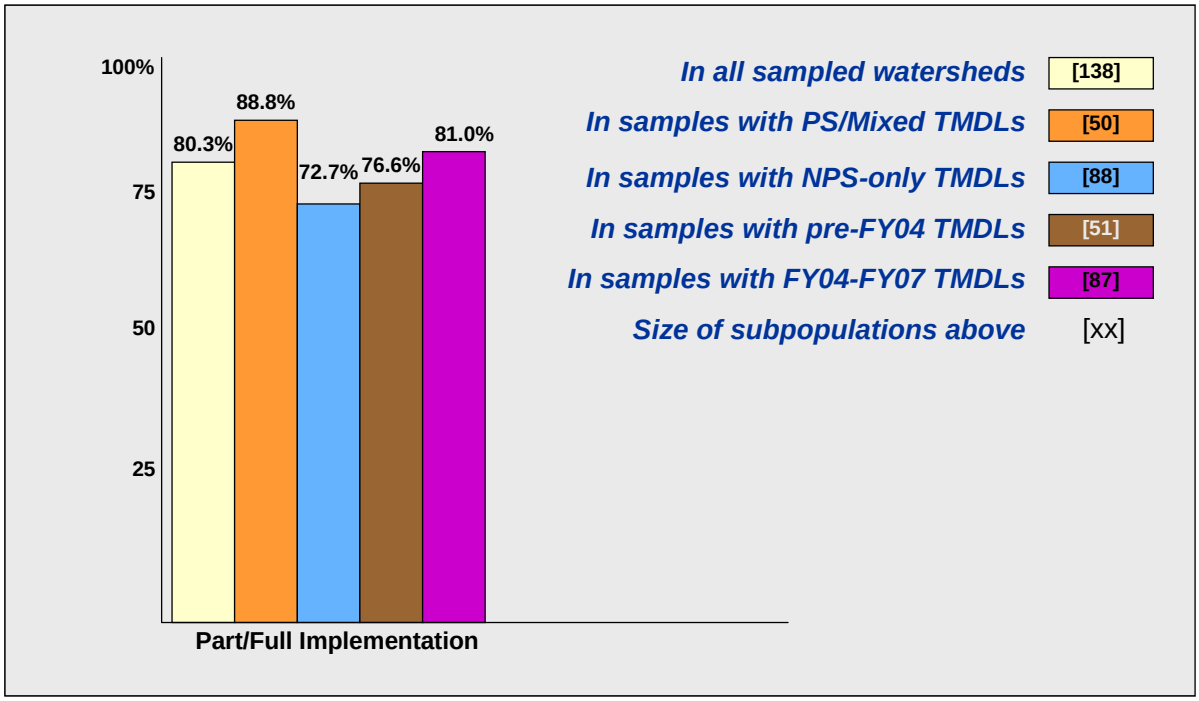
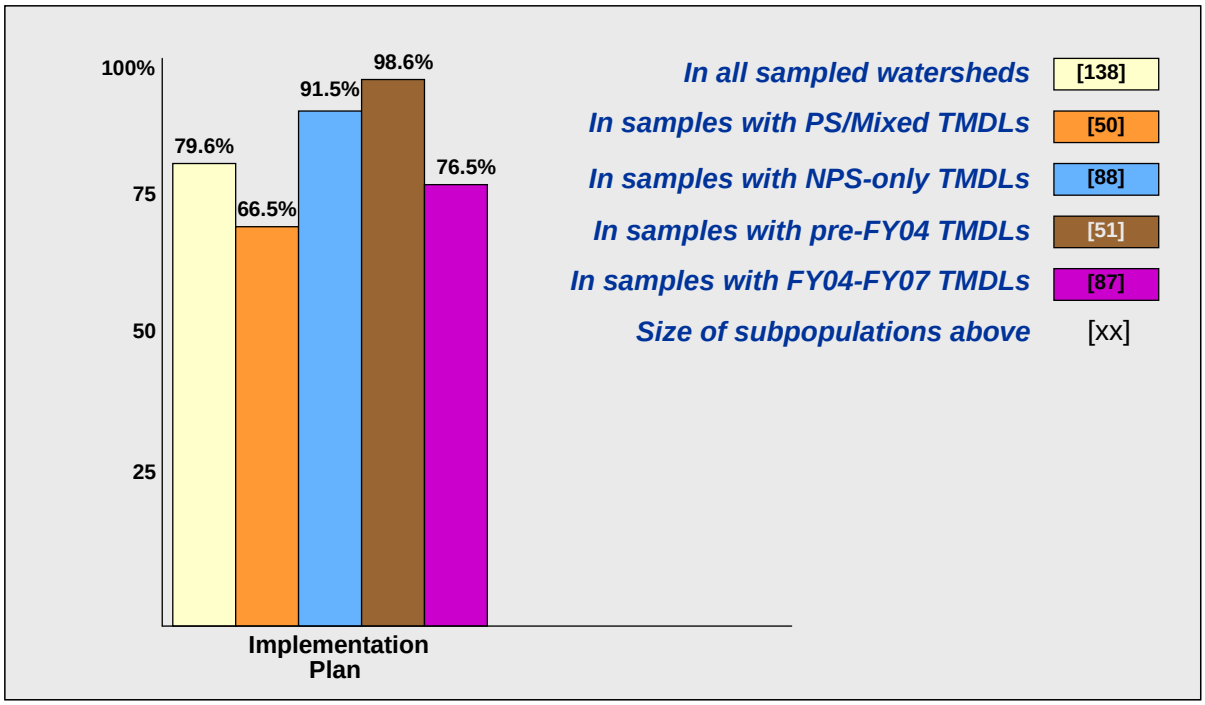


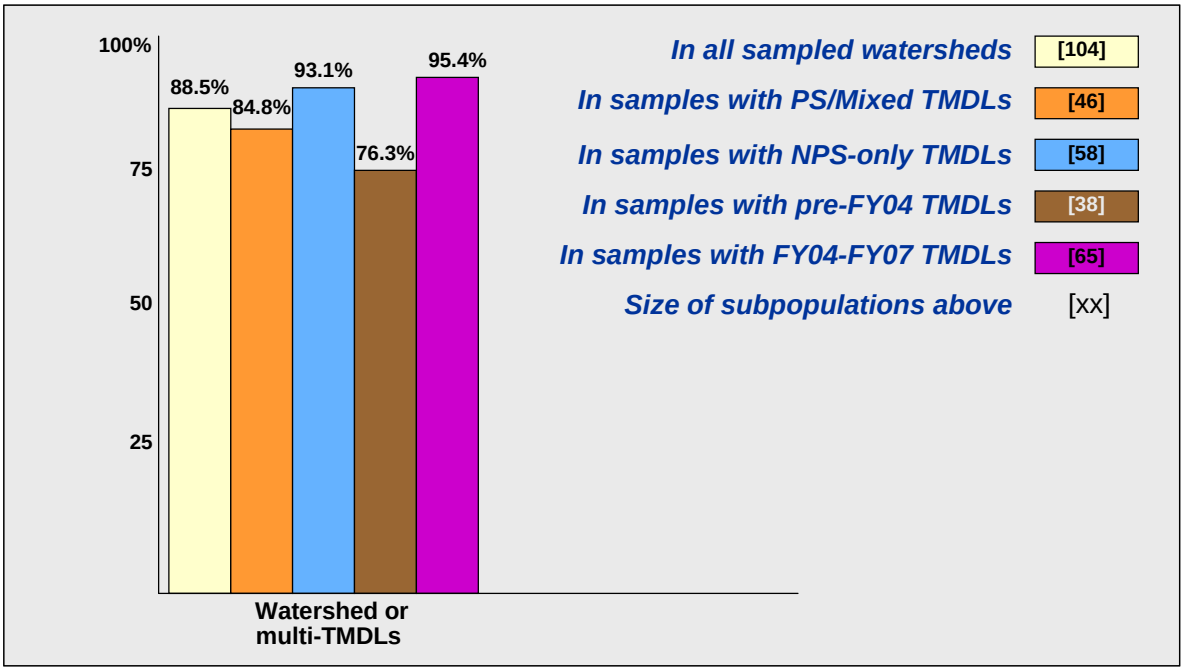
Figure 3. Estimated percent of TMDLs in sampled subpopulations that have an implementation plan. Note that 22.1% more implementation plans existed for older than newer TMDL samples, and 25% more for NPS-only than for mixed TMDLs.



Statement 6 addressed the rates at which TMDLs in the sample were found to have a finalized implementation plan. Again, the data allow for comparison among the sample and the four subpopulations (Figure 3). The estimated overall rate observed in the regional sample was that nearly 80% of the Region's TMDLs have a completed implementation plan. Among the subpopulations, older TMDLs with plans (98.6%) exceeded newer TMDLs with plans (76.5%). The NPS-only TMDLs with plans (91.5%) also exceeded the mixed TMDLs with plans (66.5%).

Because of the growing popularity of developing large watershed TMDL studies that encompass up to hundreds of TMDLs per study in the Region 5 states, our study also analyzed the frequency of multi-TMDL or 'watershed TMDL' efforts and the proportion of partially to fully implemented samples that came from multi-TMDLs. The results of the analysis to quantify statement 7 demonstrated that multi-TMDL approaches are well established regionally and appear to be increasing in recent years. Among subpopulations, all far exceeded three-quarters

Figure 4. Frequency of partially to fully implemented TMDL samples associated with watershed or multi-TMDLs, as separate from those developed as single TMDLs on single water bodies or segments. Note the percentage rise in this characteristic from older to more recent TMDLs is 19.1%. Figures not weighted.

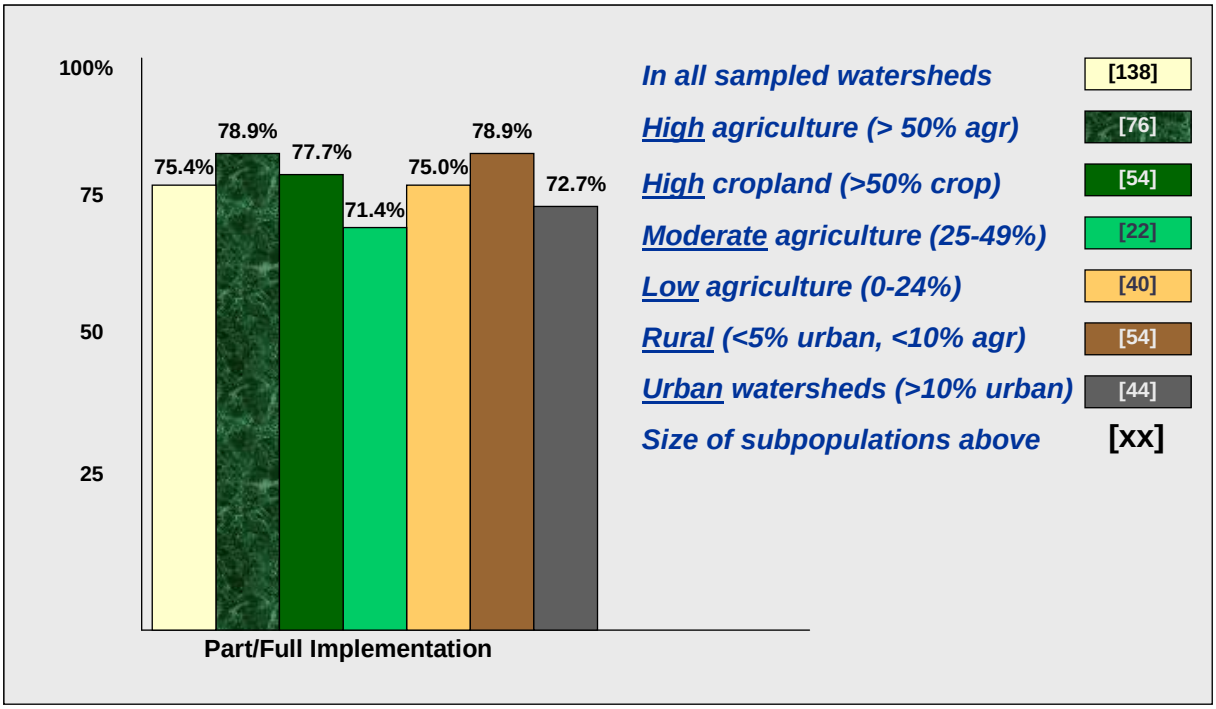


from multi-TMDL efforts. NPS-only TMDL samples (97.7%) did exceed mixed (93.4%), but not within our margin of error. Newer TMDL samples (97.5%) significantly exceeded older ones (84.3%) by a margin of 13.2%. Specifically as shown in Figure 4, we also noted that the high and increasing frequency of a multi-TMDL approach across all subpopulations existed also for that subset of the sample that had been at least partially implemented (104 of the 138 sample TMDLs).

We also explored possible associations between the TMDL implementation rates observed and potential explanatory variables, based on land use/land cover patterns in the watersheds of each sample TMDL. Land cover data were derived from the 2001 National Land Cover Dataset

(NLCD) (Homer et al 2007) and the watersheds for each sample TMDL were custom-delineated. Aggregation of land cover statistics by TMDL sample watershed enabled the calculation of land cover proportions of interest, and reaggregation of samples into strata characterized by the predominance of specific land cover patterns. We carried out this analysis to gain insight on whether implementation rates might vary with widely different land use settings, e.g., urban vs. agricultural vs. less-developed rural watersheds (Figure 5). These analyses departed from the subpopulations (older, newer, NPS-only, and mixed TMDLs) that were addressed in our original design and experimentally aggregated new subpopulations. Variation in the size (n) of the land use-related sample subpopulations implies that some results may not be within the same margin of error targeted for our primary results. Sample weighting factors were not calculated for this portion of the analysis, thus percentages represent actual proportion of sample TMDLs rather than estimated proportion of these subpopulations.

Figure 5. Percent of TMDL samples partly/fully implemented, reaggregated by predominant land cover in watershed. Some subpopulation sample sizes are too small to meet the +/- 10% margin of error, and sample weighting was not calculated. Note implementation rates across these subpopulations are similar to the region overall, suggesting that these land cover patterns do not explain implementation rates observed in this sample.



Generally, all the subpopulations we examined closely paralleled the overall region-wide implementation rate. We initially examined several levels of agriculture-dominated (including cropland and pasture) and cropland-dominated watersheds and found no evidence that these land cover types were associated with implementation rates significantly different than those observed overall. Similarly, urban-dominated watersheds did not depart from the overall pattern in regional implementation rate. We further examined a lower-intensity agriculture category, and a 'rural' category where neither agriculture nor urban uses dominated, and found no significant differences in rates in either.

DISCUSSION

Our sampling study and analysis of TMDL implementation rates provided insights into implementation across a six-state region, representing a scale at which no quantitative information on implementation previously existed. The primary seven statements around which the study was designed were able to be addressed and quantified. The findings estimate rates, quantify some associated factors, and fail to reveal other associations we tested. It is also probable that the limited resources and thus sample size available also limited the study findings we could verify within the targeted margin of error. The most prominent finding of this study is the evidence that, once approved, most of this region's TMDLs are at least partially implemented. Moreover, a developed implementation plan very frequently follows the TMDL itself in the six Region 5 states.

The findings do suggest some factors exist that may influence the rates we observed but were unable to be tested statistically. For example, the 16.1% difference between the NPS-only and the higher, mixed TMDLs rates may be due to the voluntary nature of NPS controls as compared to the enforceable, PS-permitting process affecting the implementation of the mixed TMDLs. The slightly increased implementation rate among newer vs. older TMDLs, despite the pre-2003 subpopulation's longer time for implementation, may be related to possible improvements such as greater program capacity, funding, and commitment to action, or to developing more implementable TMDLs. The NPS-only TMDLs high percentage with implementation plans, in contrast to their somewhat lower implementation rates, may be strongly correlated with 319 watershed plans. On the other hand, the finding that mixed TMDL samples had fewer implementation plans but a greater frequency of partial implementation may be related to the high rate of permits mandatorily implemented whether or not a plan exists. The higher percentage of older TMDLs with completed plans than newer TMDLs may be explainable by the fact that TMDL development, implementation, and ultimate recovery is a many-year process that is in earlier stages among the newer sample TMDLs. Together these findings send a mixed message about the relationship of implementation plan completion and actual implementation.

Overall, greater statistical power would have been particularly valuable to enable a more detailed examination and sub-categorization of the very broad 'partially implemented' category. Our continued analysis of the detailed field data gathered on partially implemented samples may produce additional, but likely less certain, insights.

Our exploratory analysis of watershed land cover was intriguing in part because it did not reveal any statistically significant differences among the widely different land cover settings we examined. We did not, however, consider this limited analysis conclusive that land cover does not contribute to explaining implementation rate differences. Based on NPS-only vs. mixed TMDL rate differences we did find, one might suspect that TMDLs in highly agricultural or rural watersheds would be significantly less implemented than urban TMDLs. The similar rates may in fact be linked to the existence of independent and very different drivers of implementation. Agricultural watersheds may have high rates due to the extensive reach of USDA funding for best management practices, whereas urban watersheds are likely much more influenced by stronger regulations and point source permitting situations. Exploratory analyses with more refined watershed land cover data, or using the data only within a corridor of much closer

proximity to the impaired water, may generate different results. Also, socio-economic factors and other geo-spatial data may be explored as possible explanatory factors.

CONCLUSIONS

From this sample-based analysis, a number of useful insights about the TMDL program's implementation rates and patterns became evident. This was the first study of its kind to investigate TMDL implementation rates across a multi-state region, and it demonstrated that, within limits, sampling approaches could be used efficiently in lieu of labor-intensive full census of thousands of TMDLs. Our sampling indicated some implementation progress in over three-quarters of the Region's TMDLs, which provides substantive evidence with which to counter questions of whether TMDLs remain "on the shelf" once completed, or actually provide a blueprint for restoration action. Even higher proportions of the region's TMDLs were found to have implementation plans or were part of a large watershed or multi-TMDL effort. Together these results suggest that TMDLs and their subsequent implementation are actively leading to restoration actions, including in a majority of cases nonpoint source control actions as well as point source control actions.

The number, complexity, and diffuse nature typical of TMDLs' recommended control actions, however, made it difficult to verify the status of every single related action. Whereas it was not difficult to determine that some or even most actions were being implemented for a given TMDL, thus placing it in the 'partially implemented' category, some individual actions remained as status unknown for many sample TMDLs. The effect of these unknowns on the estimated implementation rates varied by category. Full and partial implementation categories, based on known status, appear to be relatively unaffected. Full implementation by definition implies complete information was available and verified. Partial implementations might be full implementations if complete information were available, but typically available information included evidence of specific implemented and non-implemented practices relative to each TMDL sample. The 'not implemented' category most often contained samples for which some non-implementation was verified, and no implementation was verified, but actions of unknown status also occurred. Verifying the status of every action exhaustively, if even possible, would have exceeded our study's resources and may not have significantly changed the patterns we observed.

During the course of this study we also noted a strong interest among these states in improving their ability to track TMDL implementation progress on many if not all of their TMDLs. Although this would take significant investments and consistent maintenance, the availability of such tracking data would be very valuable for learning more about TMDL program successes, gaps, and needed improvements. Further, better tracking would make it possible for individual states to easily retrieve data such as those compiled in this sample study, and address questions about TMDL implementation and results even on state-specific scales. Improving tracking data and sampling progress in TMDL program stages are both capable of documenting program effectiveness and pointing the way to refinements for greater restoration success.

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